

SCS ENGINEERS



Kolb Road: Connection to Sabino Canyon At The Closed Vincent Mullins Landfill Tucson, Arizona

**COT Job No. SR8A
Plan No. I-2009-029**

Presented to:

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October 15, 2009
File No. 01209042.00

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SCS ENGINEERS

October 15, 2009
File No. 01209042.00

Mr. Kevin Thornton
PSOMAS
800 East Wetmore Road, Suite 110
Tucson, Arizona 85719

Subject: Landfill Subsurface Investigation
Kolb Road: Connection to Sabino Canyon
At The Closed Vincent Mullins Landfill
Tucson, Arizona

COT Job No. SR8A
Plan No. I-2009-029

Dear Kevin:

SCS Engineers (SCS) is pleased to provide this report describing the methodology and findings of our subsurface investigation of the western portion of the Vincent Mullins Landfill in Tucson, Arizona.

SCS appreciates the opportunity to assist you with this exciting project. If you have any questions, please feel free to contact Brad Johnston at 602-840-2596.

Sincerely,



Bradley Johnston, RG
Vice President
SCS ENGINEERS



Bob Isenberg, PE
Project Director
SCS ENGINEERS

N:\DATA\PROJECTS\2009\01209042.00 PSOMAS Kolb Rd Extension\Report\Kolb Rd Site Characterization Report Final 10-15-09 R1.Doc



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1 INTRODUCTION

PURPOSE

SCS Engineers (SCS) was retained by the City of Tucson to investigate subsurface conditions at the closed Vincent Mullins Landfill for a proposed new paved roadway to be constructed within the waste footprint along the west slope. Based on the conditions encountered and proposed roadway alignment and preliminary grades, SCS was requested to present options for supporting the roadway.

BACKGROUND

The Vincent Mullins Landfill is a closed landfill located north of the intersection of Speedway Boulevard and Kolb Road in Tucson, Arizona. A site location map is presented as Figure 1 in Appendix A. The landfill operated from approximately 1976 to 1987 and the Arizona Department of Environmental Quality (ADEQ) granted closure of the site in 2007 after placement of a soil cap with a minimum thickness of three feet. The site has an active landfill gas recovery system consisting of vertical gas wells, headers, sumps, and a blower flare station.

2 GEOTECHNICAL INVESTIGATION BORINGS

NUMBER AND LOCATIONS

A total of seven (7) geotechnical borings designated as B1 through B7 were performed within the limits of the Vincent Mullins Landfill along the proposed alignment of Kolb Road. The borings were conducted on May 26 and 27, 2009. SCS's field representative monitored the borings and prepared detailed logs included in Appendix B. Photographs of the borings are included in Appendix C. The boring locations and elevations were surveyed. Boring elevations are indicated on Table 1 and range from 2532.2 feet to 2536.6, a difference of 4.4 feet.

Figure 2 in Appendix A depicts the borings in relation to the proposed roadway alignment and landfill limits. Three of the borings, B2, B4 and B6 are along the western edge of the proposed Kolb Road (just inside the assumed edge of the waste) and the remaining for borings B1, B3, B5 and B7 are along approximate centerline. Relative to the roadway alignment, the borings extend from the north end of the landfill to the south end, a distance of approximately 450 feet, and thus provide good coverage for design purposes.

METHODOLOGY

Yellow Jacket Drilling Services (Yellow Jacket) provided equipment and personnel for the borings. Each boring was advanced using a rotary drill rig and hollow-stem augers under the direction of Ms. Patricia Hartshorne, RG of SCS. An unlined split spoon sampler was used to collect samples of wastes and soil at 5- or 10-foot depth intervals. Prior to performing fieldwork, SCS contacted Arizona Blue Stake to perform location of public underground utilities.

A land survey was also performed to mark the locations of the intersections of landfill gas (LFG) header and lateral piping using a previous survey performed during construction. All boring locations but one (B6) were confirmed to be at least 20 feet from the locations of the header and lateral piping. Due to the proximity to the header piping, the location of B6 was cleared to a depth of 7 feet below ground surface (bgs) by Yellow Jacket using an air knife prior to drilling using the auger.

During drilling, the upper 3 feet of soil cover were segregated until drilling was completed. Upon completion of each boring, three or four bags of 3/8-inch bentonite chips were placed into the boring in order to extend from the base of the boring to above the bottom of waste. The waste cuttings and soil were then backfilled into the boring and the upper 3 feet of soil cover was replaced and compacted by hand. Leftover waste cuttings and soil were loaded into a pickup truck, covered, and transported for disposal at the City of Tucson Los Reales Landfill.

FIELD OBSERVATIONS

The seven borings encountered the same three basic material types (top to bottom): soil cover, waste, and native sandy soil and rock. Table 1 below summarizes the material layer thicknesses from the borings:

Table 1. Boring Log Summary

Boring	Location Relative to Proposed Road	Total Depth (feet)	Surface Elevation (MSL, feet)	Soil Cover Thickness (feet)	Waste Thickness (feet)	Native Soil/Rock Layer
B1	Centerline at North end	35	2532.2	11	21	>3
B2	West edge	20	2532.4	12	4	>5
B3	Centerline	35	2534.0	13	20	>2
B4	West Edge	25	2533.5	13	7	>5
B5	Centerline	40	2535.4	6	26.5	>5
B6	West Edge	30	2535.0	13	10	>7
B7	Centerline at South End	55	2536.6	6	38	>11

Figure 3 graphically depicts the borings side-by-side and with relation to the surface elevation. It is evident that borings along the west side of the proposed road (B2, B4 and B6) have shallower waste thickness of 4, 7 and 10 feet, respectively, whereas borings along the centerline (B1, B3, B5 and B7) encountered waste thicknesses of 21, 20, 26.5 and 38 feet, respectively. Since the surface elevation at the borings varies by a maximum of 4.4 feet, the bottom of the waste

becomes deeper toward the east and is several times thicker on the east side of the road compared to the west. As will be explained in the next section, this finding is significant in that settlement potential of the waste along the east side will be proportionally higher than along the west side.

Soil Cover

The soil cover, according to the landfill closure specifications, consisted of 3 feet of monolithic engineered fill. The upper layer of the cover was a 2-foot thick infiltration control layer compacted to 90% of maximum Proctor (ASTM D698) dry density. The lower 1 foot layer of the cover was a foundation layer placed over the existing soil cover, which was a minimum of 1 foot thickness over waste.

Based on observation of soil cuttings from the seven borings, the soil cover was relatively uniform in texture and there was no obvious visual change between the different layers. Cobbles were encountered in the soil cover. This layer appears to have been compacted. Based on thickness measurements from the borings, the soil cover is much thicker than 3 feet at all boring locations, averaging 10.5 feet thick. This additional thickness is due to cover soil that was placed on top of the waste during active landfill operations, before installation of the final cover.

Waste

In general, the waste layer varied in thickness from 4 feet at B2 to 38 feet at B7. The average waste thickness is 18 feet. The waste appears to be typical of household type wastes, although is not highly organic or odorous. The degree of decomposition ranges from low to moderate. Identifiable components in the waste include soil mixed with plastic and plastic bags, paper, newspapers, metal cans, cardboard, cloth, wire, glass, etc. There were no obvious differences in waste types between borings. The wastes were relatively dry in the western borings and in the upper portions of the centerline borings, becoming relatively moister, darker, and more odiferous with depth. Wet conditions were seen only in boring B3 in a sample collected at 15 feet bgs. The amount of decomposition of waste varied, with drier portions of borings showing more decomposition than moister portions. Dates were found in newspapers in two borings: November 17, 1979 in boring B1 and July 1985 in boring B7.

Native Soil

Underlying the waste at all locations is a native soil consisting of moist, reddish brown sand with gravel. Cobbles were encountered in native soil in borings B2, B5, and B7; no sample of native soil was able to be collected from the base of boring B7 due to the presence of cobbles.

3 PRELIMINARY SETTLEMENT ANALYSIS

POTENTIAL SETTLEMENT OF UNDERLYING MATERIALS

It is anticipated that placing new grading fill and a flexible pavement over the existing landfill surface, along with future vehicles loadings, will result in settlement of material underlying the pavement. Settlement will occur within the upper layer of cover soil that is already in place, as

well as within the underlying waste material. The former will be relatively small (less than an inch) as it appears the fill consists of relatively uniform inorganic material and received some compaction upon placement, and will be completed within a time period of a few days or weeks. The latter settlement component will be somewhat larger as the waste contains organic material, received compaction typical for landfills of that age and the waste is therefore considered compressible.

Two factors contribute to the potential waste settlement component: (1) load-related compression from stresses imposed by new grading fill, pavement and vehicles, and (2) on-going decomposition of organic components contained within the waste. Settlement of the grading fill is described in traditional soil engineering references, and is well understood and estimated with many methods. However, waste settlement involves several processes as described by Sowers (1970):

- on-going decomposition of organic matter,
- raveling (internal shifting and migration) of particles over time
- compression due to self-weight,
- impact of new loadings from structural fill and from the road and fill loadings

Expected settlement within the waste is conservatively assumed to be mimicked at the surface. In other words, the pavement surface will reflect settlement of the underlying waste and “bridging” is unlikely to occur due to the lateral extent of the waste. Therefore, settlement of the proposed new pavement and other site improvements may occur in response to expected settlement of the in-place waste and its overlying fill.

Accurate predictions of settlement rate and the overall magnitude of settlement of waste are difficult to make under any circumstances due to various unknowns such as exact composition and placement of refuse, rate of decomposition of woody and paper refuse, distribution, age, and moisture content of existing refuse materials. However, based on generally accepted empirical models and the results of the recent borings, we have considered potential short term and long term estimates of settlement.

Initial Settlement

This stage of waste settlement, also referred to herein as short-term settlement, occurs over a short period of time (several weeks to months) and is directly related to waste compression properties and physical loads applied from new soil fill, roadway pavement section, and traffic loading. Initial settlement will occur relatively rapidly, and may not be detectable as the area is being filled.

Although sophisticated mathematical models exist to estimate waste settlement, such models are only as good as the input data. Given the limited data available, it is most appropriate to utilize a basic compression model such as that developed by Hough (1957), and incorporate the waste settlement characteristics developed by Sowers, 1970.

In Hough’s model, the basic one-dimensional settlement relationship for compressible materials is described in Equation 1 as follows:

$$\text{Settlement, } S = H * \frac{C_c}{1+e} * \log(1 + \Delta P/P)$$

where, S = Total settlement of the compressible layer under study (the waste)

H = original thickness of the compressible layer

Cc = coefficient of compression of the compressible layer

e = initial void ratio of the compressible layer

P = initial stress at center of compressible layer

ΔP = stress increase due to new loading

Based on Sowers' work, Cc for MSW ranges from 0.03*e to 0.09*e for conditions “unfavorable” and “favorable” to settlement, respectively. In this case, given the age and type of the waste, and the likelihood that it has received some degree of compaction (even if small), we can assume the lower end of the range, meaning Cc = 0.03*e to 0.06*e. This means that the waste will not compress as much as freshly placed waste, but due to the unknown nature of compaction, may still compress under new loadings.

The initial void ratio, e, of the waste (current condition) has been estimated to be in the range of 2.0 to 3.0. This is typical for most solid waste materials. At these void ratios, and assuming a specific gravity of the waste at about 1.5, the resulting waste density (wet density) will be somewhere between 800 and 1000 pounds per cubic yard, which is typical for this type of landfill.

Proposed fill for grading purposes may add up to 5 feet of new soil which equates to a uniform surface loading of about 600 psf. Another load contribution is the vehicular traffic itself. As traffic these loads are transient, such loads can be conservatively modeled as a static load equivalent to approximately 3 feet of soil, or 375 psf. Combining the fill, pavement and static-equivalent vehicle loads and assuming a unit weight of 125 pounds per cubic foot, the new loadings will add up to approximately 1000 pounds per square foot. However, this is the initial new loading and it is highly likely that as settlement occurs during construction, the actual depth of new fill soil will be 20% to 25% higher, say closer to 6 to 8 feet. Therefore, a more realistic estimate of new loading is 1250 psf.

The spreadsheets provided in Appendix D show settlement estimates for various ranges in void ratio and compression index, as well as waste thickness.

As noted above, initial settlement stages will begin to occur as the new fill and pavement is placed and may not be very noticeable to the casual observer as the surface will be changing due to filling. The construction contract should address this issue, as estimated fill is likely to be significantly greater than would be calculated. Settlement of the final fill surface will continue, but at decreasing rates, for a period of several weeks to months after completion

Again, note that these are only estimates, and should be viewed as “ballpark” values. Without data from a field load test, or specific waste property data, including compressibility information, it is the best that can be done analytically.

Using this approach, SCS has estimated initial (or short-term) refuse settlement in Table 2 below:

Table 2. Estimated Initial Settlement

Boring	Waste Depth (feet)	Load Related Settlement for e=2.0 (inches)	Load Related Settlement for e=3.0 (inches)	Average Predicted Load Related Settlement** (inches)
B1	21	5.3	7.1	7
B2	4	2.2	2.8	3
B3	20	5.3	7.0	7
B4	7	3.1	4.0	4
B5	26.5	6.0	7.9	7
B6	10	3.7	4.8	5
B7	38	6.7	9.1	8

**Values rounded up to the nearest inch

Secondary Settlement

For the long term condition, which would occur slowly and continually after initial pavement construction, we assumed that the refuse exhibits secondary settlement (also referred to herein as long-term settlement) resulting from decomposition of the organic components, similar to municipal solid refuse, as described by Sowers (1973) and Yen & Scanlon (1975). This aspect of settlement is generally not impacted by the new surface loadings but would occur each year as the refuse continues to decompose, but at decreasing rates as discussed below.

To estimate secondary settlement, we use the following Equation:

$$\Delta H = H (\dot{\alpha}) / (1 + e_0) * \text{Log} (t_2/t_1)$$

Where

ΔH = settlement of a refuse layer of thickness H

$\dot{\alpha}$ = coefficient of secondary compression, e.g., 0.18 as described above

e_0 = initial waste void ratio (assumed equal to 3.0)

t_1 = average age of refuse placement (a constant, taken as ~20 years, which is a conservative assumption for this model)

t_2 = total years since end of refuse placement (~20 years plus 5 and 10 years, etc)

The range of secondary compression indexes ($\dot{\alpha}$) was estimated as follows:

Conditions “favorable to decomposition,” $\dot{\alpha} = 0.09$ * $e_0 = 0.27$ (greater potential for settlement); conditions “unfavorable to decomposition,” $\dot{\alpha} = 0.03$ * $e_0 = 0.09$ (less potential for settlement)

Recognizing that the underlying refuse has an average age of more than 20 years, is relatively compact, does not contain a large amount of organics, is relatively dry and exists in an arid environment, we used the factor $\alpha = 0.18$, which puts the secondary compression index toward the middle to low end of the range estimated above, where there is less potential for settlement.

Using this approach, SCS estimated secondary (long-term) refuse settlement as follows:

Table 3. Estimated Secondary Settlement

Boring Location	Refuse Thickness (feet)	Settlement 5 years after construction (inches) $t_2/t_1 = 25/20$	Settlement 10 years after construction (inches) $t_2/t_1 = 30/20$
B1	21	1.5	2.7
B2	4	0.3	0.5
B3	20	1.4	2.6
B4	7	0.5	0.9
B5	26.5	1.9	3.4
B6	10	0.7	1.3
B7	38	2.7	4.8

Total Settlement

Combining short term and long term settlement estimates for the refuse material, and short term settlement from within the overburden soil, total settlements are estimated for 10 years after initial construction in Table 4 below:

Table 4. Estimated Total Settlement After 10 Years

Boring Location (waste thickness)	1 Soil Cover Settlement* (inches)	2 Short-term Refuse Settlement* (inches)	3 Long term Refuse Settlement**For 10 years after construction (inches)	1+2+3= Total Settlement** (inches)	Differential Settlement= 0.5* Total Settlement (inches)
B1 (21')	< 1	7	3	10	5
B2 (4')	< 1	3	1	4	2
B3 (20')	< 1	7	3	10	5
B4 (7')	< 1	4	1	5	2.5
B5 (26.5')	< 1	7	4	11	5.5
B6 (10')	< 1	5	2	7	3.5
B7 (38')	< 1	8	5	13	6.5

*nominal value for existing soil cover material

** rounded up to nearest inch

This table indicates that at B2, where the waste is only 4 feet thick, total settlement will be approximately 4 inches, whereas at B7, where the waste is 38 feet thick, total settlement will be approximately 13 inches. The differential settlement between these two points is 9 inches over a

distance of 380 feet, or about 0.2%. This amount of differential settlement is relatively low and final road grades can be adjusted to accommodate this differential settlement.

The three components of settlement listed in the table above - (1) soil cover settlement, (2) initial (short-term) waste settlement and (3) secondary (long-term) waste settlement - would be expected to occur beginning with the filling and pavement construction phase and to continue for a period of time after construction is complete. Accurate, site-specific estimation of the duration and rate of these settlement components is not possible without large scale field testing or monitoring from construction of the initial phase. However, a general estimate can be made of at least 6 months to 2 years for the major portion. Beyond 2 years, the settlement rate will be relatively low, but is not zero. Based on the waste thickness measurements, total settlement is anticipated to be somewhat greater on eastern side of the road where the waste is thickest.

These values should be considered as approximate; more accurate estimates can only be provided with long-term settlement monitoring of the site.

Differential Settlement

Based on the information analyzed for this geotechnical study, it should be assumed that differential settlement between any two points will be equal to approximately one half ($\frac{1}{2}$) of the above estimated settlement amounts. This estimate of differential settlement is based upon generally accepted experiences for compressible materials.

4 SITE IMPROVEMENT OPTIONS

The following section is a general discussion of foundation issues relating to placing structures over waste.

Foundation Improvement Options

For the Kolb Road Project, we have assumed that the waste is not as compressible as one would assume for a fresh, highly organic waste. It does not contain large amounts of organic matter (based on boring log descriptions), is relatively dry, and a long period of time has passed since placement. This means that some organic decomposition has occurred. However, the waste will compress over time and under load, which will result in settlement of the paved surface. This settlement will occur during construction and continue for a long period of time afterward. Large scale field compression tests could be performed to supplement the analytical computations and provide more accurate predictions, but given the relatively low magnitudes of settlement and light loadings, such testing may not be timely or justifiable.

Should settlement predictions indicate values that are not tolerable for the proposed road, foundation improvement methods or deep foundation support systems may be necessary.

Foundation improvement options would include:

- waste excavation and replacement with compacted fill,
- deep dynamic compaction (DDC) or similar in-place densification technique
- geogrid reinforcement

- pre-loading or surcharging.

The initial costs for deep foundation support systems using piles, piers, caissons, are likely to be relatively high, but these options would minimize future maintenance expenses due to roadway settlement that is likely to occur with other options.

Waste Removal Option

This is a relatively expensive option that requires the complete removal of waste materials down to native soil, followed by replacement with engineering compacted fill. At the deepest point, the waste excavation alone would be 38 feet plus the 6 feet of soil cover, or a total of 44 feet. At the shallowest it would be 4 feet plus 12 feet, or a total of 16 feet.

The width of such an excavation would need to be sufficient so that compacted fill is present within an envelope measured from a 1:1 (45-degree) slope from the edge of the road to the bottom of the excavation.. Allowing for a 2:1 excavation sideslope, such an excavation would be 264 feet wider than the proposed Kolb Road width. Such an excavation would involve a significant volume of waste removal and re-disposal. At the shallowest location near B2, a waste removal excavation would be 96 feet wider than the road width.

Partial removal of the waste followed by replacement with compacted fill is not a recommended approach as that option could actually result in potentially larger settlements. This is since a partial waste excavation would involve removing a portion of the lighter weight waste and replacing it with heavier soil, thereby triggering additional settlement.

Deep Dynamic Compaction

In cases where waste or soil ground stabilization is needed to depths of less than 25 to 30 feet, a method known deep dynamic compaction (DDC) may be employed. This is a proven method to stabilize soft or weak soil materials that has been used for several decades. The method is simple: repeatedly raise and drop a large heavy concrete mass on top of compressible or weak soils a sufficient number of times to compact and strengthen the soil. The number of drops, height of each drop, and weight of the rammer is a function of the depth and type of soil to be impacted. For pure refuse materials, containing mostly organic matter, the maximum depth of influence only approaches 25 to 30 feet.

The DDC process occurs over the entire building pad area, along road and utility corridors, and to some nominal distance beyond. Small or large craters are formed as the soil is compressed, which must be re-leveled with new fill. Because this method will compress material below and to the sides of the impact areas, it has the potential to disturb nearby sensitive underground structures or utilities. As such, it could disturb nearby landfill gas control equipment such as wells and piping. The allowable safe distance between the DDC impact areas and underground structures will vary from site to site, depending on the material encountered and utility design, and should be discussed with the contractor. It may be prudent to conduct a field test that includes vibration monitors to detect ground motions at various distances. It should be noted that several of the landfill gas wells and associated piping are located within the planned

alignment and will therefore need to be moved and replaced for road construction, so it may be possible to manage this issue with proper sequencing of activities.

DDC does not eliminate settlement, but will reduce settlement to relatively low and tolerable levels depending on the building design and type. There are numerous examples of DDC being used in the US.

Cost to perform DDC are site-specific, but a rule of thumb is to allow for \$50,000 to \$60,000 for mobilization and \$1 to \$2 per square foot of treated area.

Geogrid Reinforcement

Geogrids are manufactured thermo-plastic products that are placed within layers or lifts of compacted fill, or over soft ground, to add tensile reinforcement. They are typically made of polyethylene, polyester, and are deployed in rolls directly on the ground.

While geogrids are capable of improving soil bearing capacity and reducing the potential for abrupt differential settlement between adjacent areas, geogrids will not reduce total settlement for sites with significant thickness of underlying compressible materials. In other words, if there is a compressible soil layer below the geogrid, that layer will still compress over time and under load of the new road. Therefore, it is unlikely that geogrids alone will provide sufficient ground improvement in this case, other than in localized areas, under roadways or utilities. We do recommend to use geogrids in the pavement design to reduce the impact of differential settlement.

Surcharging (preloading)

Surcharging is another time-tested method of improving soft ground conditions, including landfill waste. The surcharge process involves placing several feet or more of soil across a proposed road or building area and allowing the soil to remain in place for a year or more. The weight of the soil compresses the underlying soft soil or waste for a period of time and is then removed. The pre-compressed layer will have a reduced potential for settlement when the final load or structure is placed over it.

The height of the surcharge, and lateral extent, are functions of the proposed structure. Typical guidance is for a surcharge loading (pressure) to be equal to 1.5 to 2 times the planned pressure of the new structure and that the surcharge remains in place until the rate of settlement is reduced to an acceptable level. In the case of Kolb Road, the surcharge height would be a function of the final grading plan. If, for example, 5 feet of soil fill was required to reach pavement grades, the minimum surcharge would be equal to 5 feet plus 3 feet to account for traffic loads times 1.5 or 12 feet total. The lower most one to two feet of surcharge soil will likely settle into the ground and remain in place as part of the final subgrade.

An advantage of surcharging over the other methods is that monitoring of settlement rates is performed as part of the method. This allows the engineer to track the progress of settlement and make quantitatively based predictions as to when the surcharge may be removed and how much settlement remains. Typically, the initial rate and magnitude of surcharge-induced settlement will be relatively large; over time, the rate and magnitude will be reduced and level off. Based

on the settlement trend, which often follows a logarithmic relationship, a large portion of the surcharge-induced settlement will occur in the initial several months. The disadvantage of surcharging is the time to complete the surcharge is not known until several sets of readings are available, and cost of bringing in and removing fill may be high in areas where fill is costly, or not readily available near the site.

5 RECOMMENDATIONS

Based on the results of borings and settlement estimates, it is concluded that the existing waste will settle between about 4 and 13 inches after road construction. The settlement will occur at decreasing rates and is related to total new loads and waste decomposition. Removing the waste will be costly, in the range of \$5 to \$10 per cubic yard for excavation, and which does not include disposal costs. Waste excavation is not warranted economically in this case.

Deep foundation support systems could include piles, piers, or caissons to support the roadway structure. The initial cost for these systems may be relatively high, but these options would minimize future maintenance expenses due to roadway settlement that is likely to occur with other options. Additional subsurface investigation (borings and testing) may be required to design the deep foundation system. Such a design will need to consider vertical loadings from the road fill, pavement and traffic, plus downdrag on the piers due to waste compression. The potential environmental impact of extending a pile or pier through the waste and into underlying native materials also needs to be considered as the pile or piers may act as flow conduits.

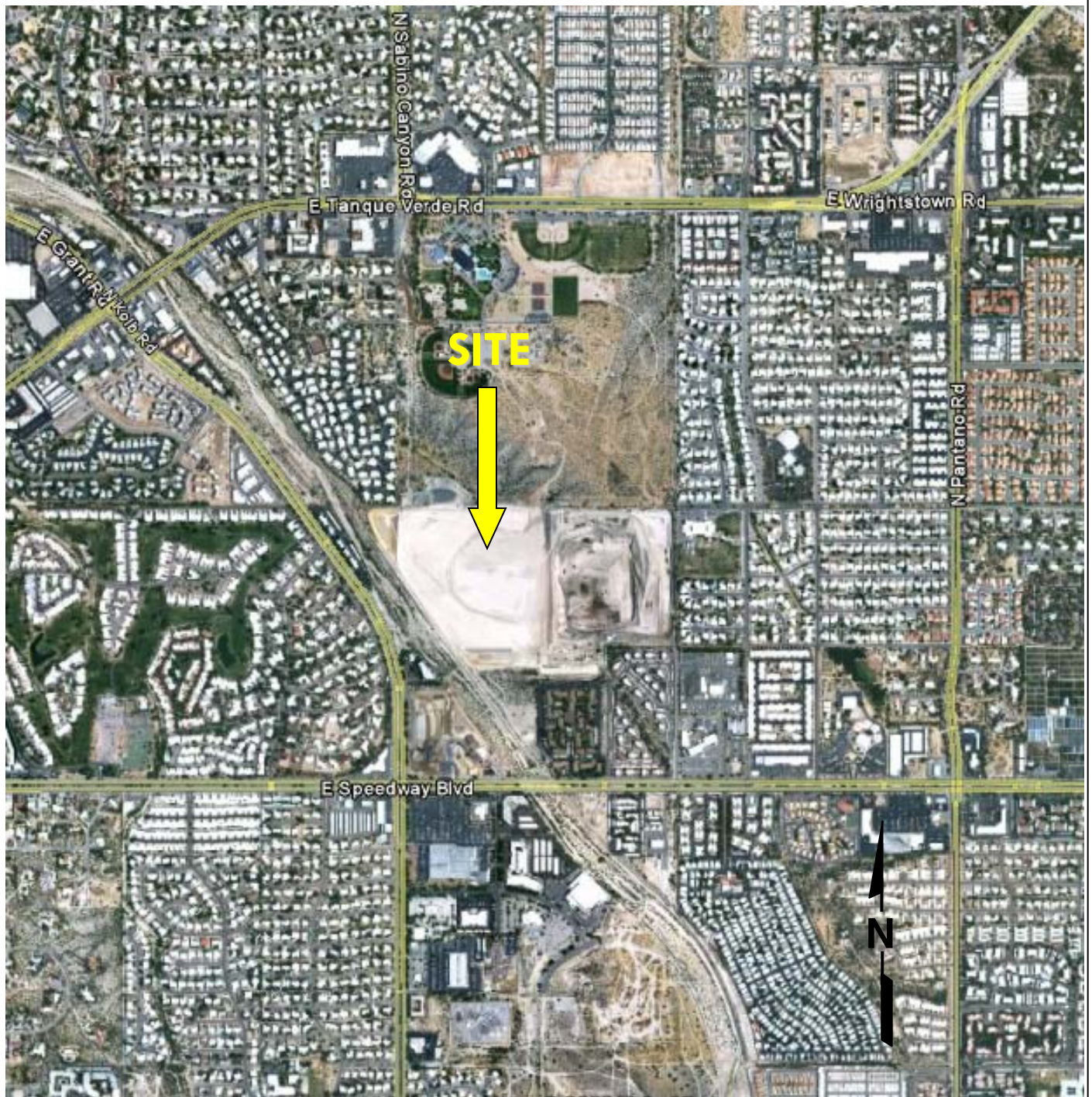
Deep dynamic compaction (DDC) is a proven method to stabilize the subgrade, but does not eliminate settlement entirely because the remaining organic matter may eventually degrade. However, it may be warranted if time does not permit a surcharge approach (as discussed below), or if settlements must be reduced to a minimum.

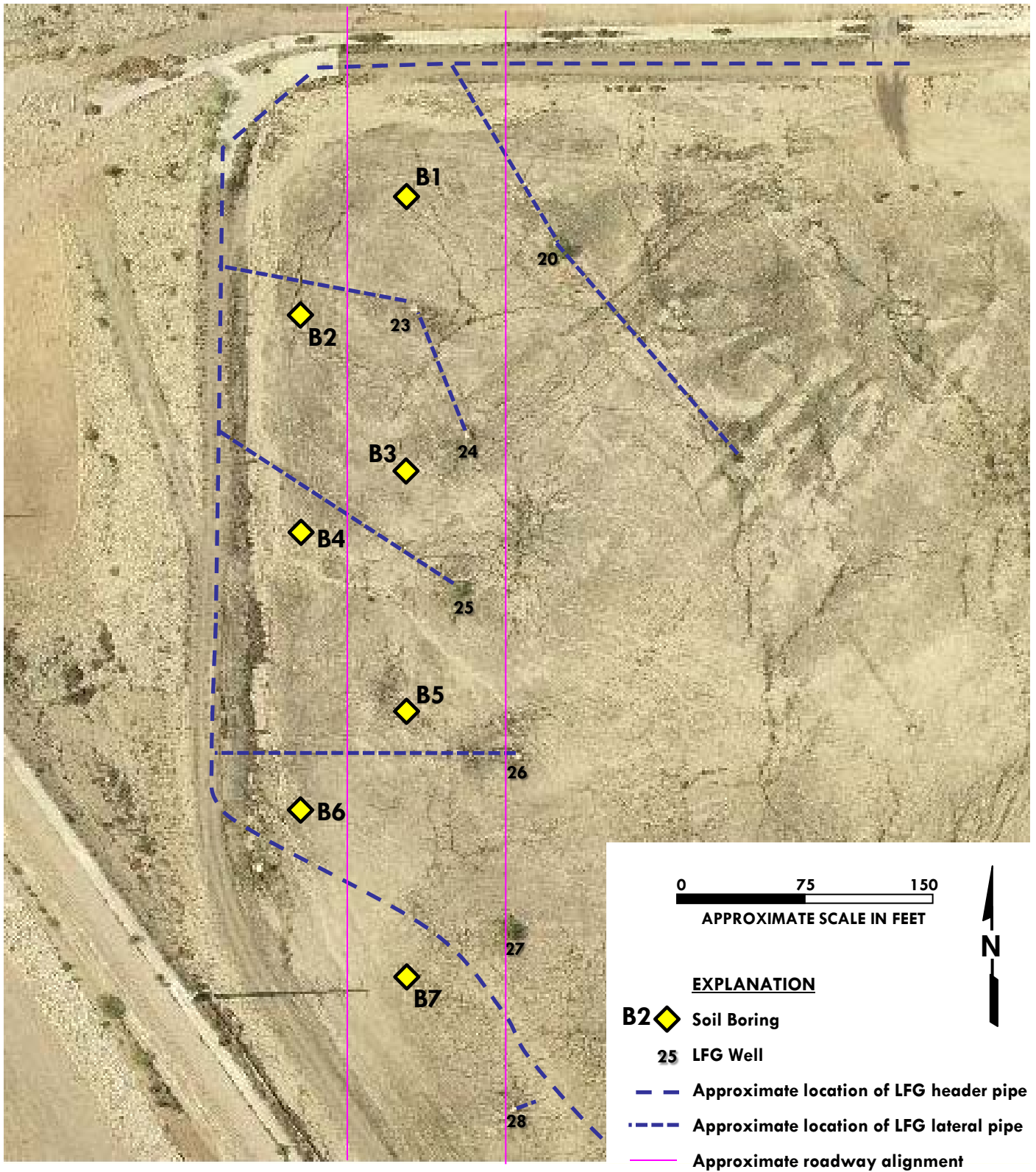
Should time be available to perform surcharge, this would be a reasonable and cost-effective option. Because fill will reportedly be required to achieve final grades, an excess of fill could be placed as surcharge, and then cut back to final grades after the surcharge process is finished. Availability of cost-effective surcharge material can be a key issue, as is monitoring of settlement during the surcharge process.

Regardless of the method selected, it would be beneficial to begin measuring settlement of the surface as soon as possible at several locations, taking readings every 3 to 4 months. This would provide a real-time indication of secondary compression. Conventional land surveying methods are adequate and relatively inexpensive.

APPENDIX A

FIGURES

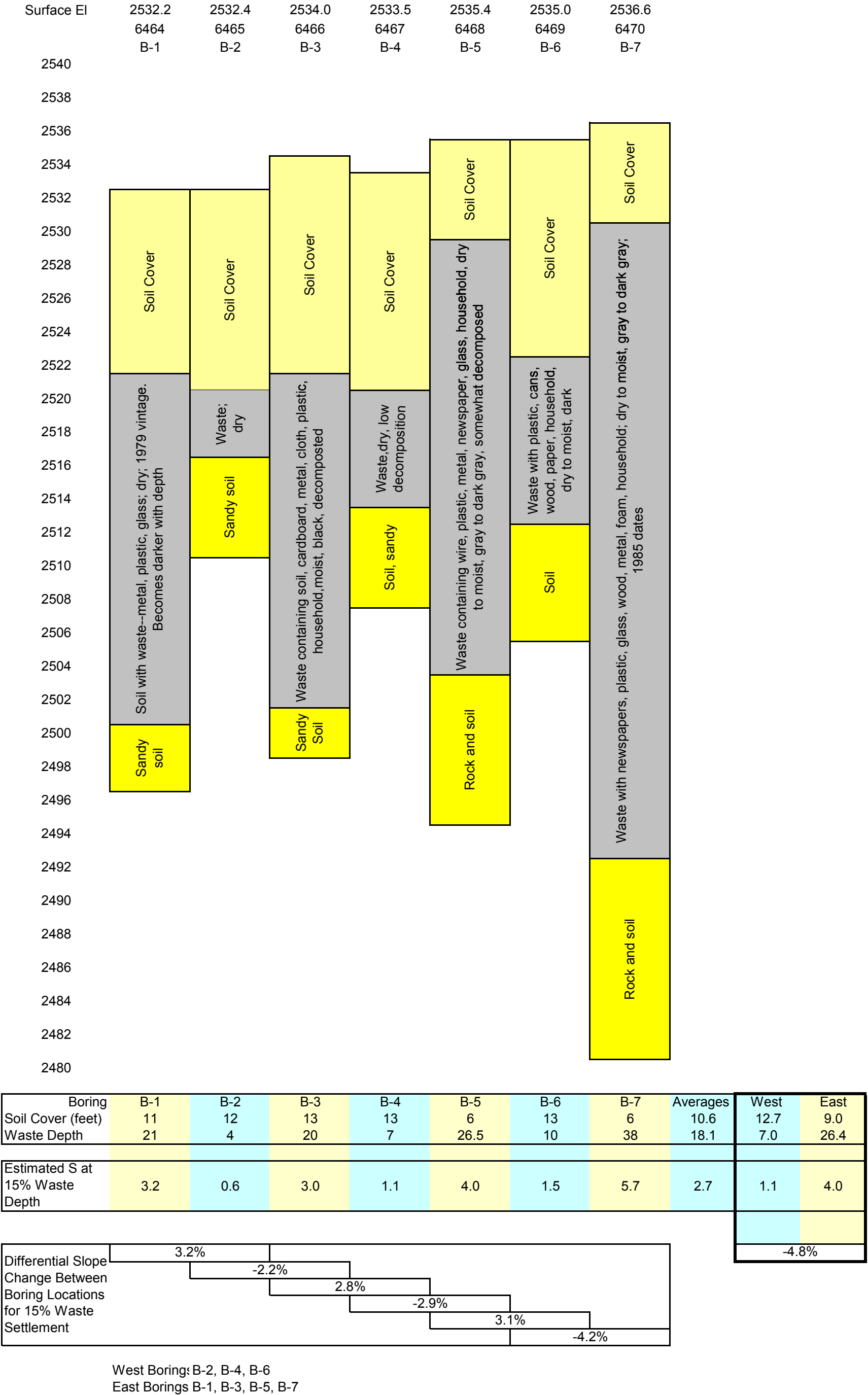




Source: PCDOT MapGuide Website, 2008 Aerial

Disclaimer: This figure is based on available data. Actual conditions may differ. All locations and dimensions are approximate.



Figure 3 - Graphical Representation of Boring Logs



APPENDIX B

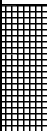


BORING LOGS

Project Name: PSOMAS – Vincent Mullins LF/Kolb Rd Project				Log of Boring No: B1		Page 1		of	2
Logged/Checked by: Patricia M. Hartshorne, R.G.				WL Datum: N/A					
Date Started: 5/27/09				Datum Elev: N/A					
Date Completed: 5/27/09				WL Below Datum: N/A					
Contractor: Yellow Jacket Drilling				ATD/Time: 35 FT/10:45					
Drilling Equipment: Hollow-stem auger				Static/Date: N/A					
Depth (Ft)	Geologic Log	Blow Count	Interval	Sample Number	PID/OVA	USCS Symbol	Material Description	Comments	
5							Soil cover (per cover specifications, 3 feet monolithic engineered fill consisting of a 2 ft infiltration control layer compacted to minimum 90% of dry density and 1 ft foundation layer placed over existing cover, which was a minimum of 1 ft thickness above waste).		
15				15'			Soil changed to a darker, grayish color and waste materials began to be observed in cuttings, consisting of plastic bags, newspaper, paper, pieces of containers, metal, glass, plastic, plastic accordion hose, metal part, fabric, wrapped hose, steel can, cardboard, possible piece of asphalt, towel, and shredded unidentifiable materials. Appeared to be typical household type waste. Dry, relatively low decomposition above about 25 feet bgs. Newspapers readable – November 17, 1979 date found. Low recovery in 15 ft sample – metal, glass, plastic, and soil.		
20							Gradually increased moisture, more decomposition, dark coloration of waste.		
25				25'			Plastic, cardboard, possible piece of asphalt, and dark soil in sampler.	3 bags of 3/8" Bentonite chips added (from ~24-35')	
30									

Project Name: PSOMAS – Vincent Mullins LF/Kolb Rd Project					Log of Boring No: B1		Page 2		of	2
Logged/Checked by: Patricia M. Hartshorne, R.G.					WL Datum: N/A					
Date Started: 5/27/09					Datum Elev: N/A					
Date Completed: 5/27/09					WL Below Datum: N/A					
Contractor: Yellow Jacket Drilling					ATD/Time: 35 FT/10:45					
Drilling Equipment: Hollow-stem auger					Static/Date: N/A					
Depth (Ft)	Geologic Log	Blow Count	Interval	Sample Number	PID/OVA	USCS Symbol	Material Description	Comments		
										
							Change in drilling sound indicated probable base of waste layer and top of underlying soil.			
35				35'			Clean soil in sampler – Reddish brown SAND with Gravel, slightly moist, no odor.	TD = 35'		
40										
45										
50										
55										
60										




Project Name: PSOMAS – Vincent Mullins LF/Kolb Rd Project				Log of Boring No: B2		Page 1		of	1
Logged/Checked by: Patricia M. Hartshorne, R.G.				WL Datum: N/A					
Date Started: 5/27/09				Datum Elev: N/A					
Date Completed: 5/27/09				WL Below Datum: N/A					
Contractor: Yellow Jacket Drilling				ATD/Time: 20 FT/1137					
Drilling Equipment: Hollow-stem auger				Static/Date: N/A					
Depth (Ft)	Geologic Log	Blow Count	Interval	Sample Number	PID/OVA	USCS Symbol	Material Description	Comments	
5							Soil cover (per cover specifications, 3 feet monolithic engineered fill consisting of a 2 ft infiltration control layer compacted to minimum 90% of dry density and 1 ft foundation layer placed over existing cover, which was a minimum of 1 ft thickness above waste).		
15				15'			A few pieces of plastic bags observed in cuttings at 12 ft, but mostly soil through 15 ft. Other waste materials included glass, cloth, and plastic. Appeared to be typical household type waste. Dry, relatively low decomposition. Only thin layer of waste (glass and plastic bag) in 15 ft sample, the rest was soil.	3 bags of 3/8" Bentonite chips added (from ~11-20')	
20							Estimated base of waste layer and top of underlying soil. Waste layer may be thinner than that shown.		
20				20'			Rock in sampler on first attempt. Clean soil in sampler on second attempt – Reddish brown SAND with Gravel, slightly moist, no odor.	TD = 20'	
25									
30									

Project Name: PSOMAS – Vincent Mullins LF/Kolb Rd Project				Log of Boring No: B3		Page 1		of	2
Logged/Checked by: Patricia M. Hartshorne, R.G.				WL Datum: N/A					
Date Started: 5/27/09				Datum Elev: N/A					
Date Completed: 5/27/09				WL Below Datum: N/A					
Contractor: Yellow Jacket Drilling				ATD/Time: 35 FT/09:42					
Drilling Equipment: Hollow-stem auger				Static/Date: N/A					
Depth (Ft)	Geologic Log	Blow Count	Interval	Sample Number	PID/OVA	USCS Symbol	Material Description	Comments	
5				10'			Soil cover (per cover specifications, 3 feet monolithic engineered fill consisting of a 2 ft infiltration control layer compacted to minimum 90% of dry density and 1 ft foundation layer placed over existing cover, which was a minimum of 1 ft thickness above waste). Several pieces of thick plastic, apparently not within the main waste layer. Rock and soil in sampler.		
15				15'			Pieces of plastic bags began to be observed in cuttings. Other waste materials observed included cardboard, glass, pieces of plastic containers, metal can pieces, cloth, pieces of metal, wire, plastic, and shredded unidentifiable materials. Appeared to be typical household type waste. Moist, black, relatively decomposed. Wet layer in sampler at 15 ft, which contained plastic bags, cardboard, glass, and soil.		
25				25'			Only ~6" recovery of soil and waste (cardboard, glass, and plastic bags) in sampler. Soil was black, with dry to moist sections of waste and soil.	3 bags of 3/8" Bentonite chips added (from ~24-35')	
30									

Project Name: PSOMAS – Vincent Mullins LF/Kolb Rd Project					Log of Boring No: B3		Page 2		of 2		
Logged/Checked by: Patricia M. Hartshorne, R.G.					WL Datum: N/A						
Date Started: 5/27/09					Datum Elev: N/A						
Date Completed: 5/27/09					WL Below Datum: N/A						
Contractor: Yellow Jacket Drilling					ATD/Time: 35 FT/09:42						
Drilling Equipment: Hollow-stem auger					Static/Date: N/A						
Depth (Ft)	Geologic Log	Blow Count	Interval	Sample Number	PID/OVA	USCS Symbol	Material Description	Comments			
											
							Estimated base of waste layer and top of underlying soil.				
35				35'			Clean soil and rocks in sampler – Reddish brown SAND with Gravel, slightly moist, no odor.	TD = 35'			
40											
45											
50											
55											
60											

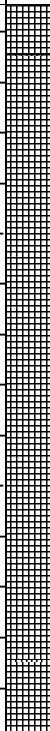

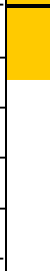
Project Name: PSOMAS – Vincent Mullins LF/Kolb Rd Project					Log of Boring No: B4		Page 1		of	1
Logged/Checked by: Patricia M. Hartshorne, R.G.					WL Datum: N/A					
Date Started: 5/27/09					Datum Elev: N/A					
Date Completed: 5/27/09					WL Below Datum: N/A					
Contractor: Yellow Jacket Drilling					ATD/Time: 25 FT/0825					
Drilling Equipment: Hollow-stem auger					Static/Date: N/A					
Depth (Ft)	Geologic Log	Blow Count	Interval	Sample Number	PID/OVA	USCS Symbol	Material Description	Comments		
5							Soil cover (per cover specifications, 3 feet monolithic engineered fill consisting of a 2 ft infiltration control layer compacted to minimum 90% of dry density and 1 ft foundation layer placed over existing cover, which was a minimum of 1 ft thickness above waste).			
15				15'			Waste materials observed included cloth, readable paper, wire, paper, plastic, metal, cardboard, and plastic bags. Appeared to be typical household type waste. Dry to slightly moist, relatively low decomposition.	3 bags of 3/8" Bentonite chips added (from ~16-25')		
20				20'			Estimated base of waste layer and top of underlying soil. Grayish colored soil in sampler.			
25				25'			Clean soil in sampler – Reddish brown SAND with Gravel, slightly moist, no odor.	TD = 25'		
30										

Project Name: PSOMAS – Vincent Mullins LF/Kolb Rd Project					Log of Boring No: B5		Page 1		of	2
Logged/Checked by: Patricia M. Hartshorne, R.G.					WL Datum: N/A					
Date Started: 5/26/09					Datum Elev: N/A					
Date Completed: 5/26/09					WL Below Datum: N/A					
Contractor: Yellow Jacket Drilling					ATD/Time: 40 FT/15:50					
Drilling Equipment: Hollow-stem auger					Static/Date: N/A					
Depth (Ft)	Geologic Log	Blow Count	Interval	Sample Number	PID/OVA	USCS Symbol	Material Description	Comments		
5							Soil cover (per cover specifications, 3 feet monolithic engineered fill consisting of a 2 ft infiltration control layer compacted to minimum 90% of dry density and 1 ft foundation layer placed over existing cover, which was a minimum of 1 ft thickness above waste).			
10				10'			Waste materials observed included wire, plastic containers, metal cans, plastic bags, plastic, newspapers, glass, cardboard, song lyrics printed on plastic sheets, cloth, and shredded unidentifiable materials. Appeared to be typical household type waste. Dry to slightly moist, gray to dark colored, somewhat decomposed. Only soil in sampler.			
15				15'			Layers of rigid plastic, plastic film, plastic bags, cardboard, newspaper, and soil in sampler.			
20										
25				25'			Metal, cardboard, glass, and plastic in sampler.			
30										

Project Name: PSOMAS – Vincent Mullins LF/Kolb Rd Project					Log of Boring No: B5		Page 2		of	2
Logged/Checked by: Patricia M. Hartshorne, R.G.					WL Datum: N/A					
Date Started: 5/26/09					Datum Elev: N/A					
Date Completed: 5/26/09					WL Below Datum: N/A					
Contractor: Yellow Jacket Drilling					ATD/Time: 40 FT/15:50					
Drilling Equipment: Hollow-stem auger					Static/Date: N/A					
Depth (Ft)	Geologic Log	Blow Count	Interval	Sample Number	PID/OVA	USCS Symbol	Material Description	Comments		
								3 bags of 3/8" Bentonite chips added (from ~31-40')		
35				35'			Estimated base of waste layer and top of underlying soil. Pulverized rock and pieces of rock in sampler.			
40				40'			Clean soil and pulverized rock in sampler – Reddish brown SAND with Gravel, slightly moist, no odor.	TD = 40'		
45										
50										
55										
60										

Project Name: PSOMAS – Vincent Mullins LF/Kolb Rd Project							Log of Boring No: B6		Page 1	of	1
Logged/Checked by: Patricia M. Hartshorne, R.G.							WL Datum: N/A				
Date Started: 5/26/09							Datum Elev: N/A				
Date Completed: 5/26/09							WL Below Datum: N/A				
Contractor: Yellow Jacket Drilling							ATD/Time: 30 FT/1150				
Drilling Equipment: Air Knife/Hollow-stem auger							Static/Date: N/A				
Depth (Ft)	Geologic Log	Blow Count	Interval	Sample Number	PID/OVA	USCS Symbol	Material Description	Comments			
5							Soil cover (per cover specifications, 3 feet monolithic engineered fill consisting of a 2 ft infiltration control layer compacted to minimum 90% of dry density and 1 ft foundation layer placed over existing cover, which was a minimum of 1 ft thickness above waste).				
10							Some small wood fragments observed.				
15				15'			Waste materials observed included pieces of plastic, cans, plastic bags, wood, paper, newspaper, glass, and unidentifiable shredded material. Appeared to be typical household type waste. Dry to slightly moist, dark colored, relatively low decomposition. Newspapers readable, but no dates were found.	3 bags of 3/8" Bentonite chips added (from ~21-30')			
25							Estimated base of waste layer and top of underlying soil. Waste layer may be thinner than that shown.				
							Soil in sampler, but not in cuttings.				
30				30'			Clean soil in sampler – Reddish brown SAND with Gravel, slightly moist, no odor.	TD = 30'			

Project Name: PSOMAS – Vincent Mullins LF/Kolb Rd Project							Log of Boring No: B7		Page 1	of	2
Logged/Checked by: Patricia M. Hartshorne, R.G.							WL Datum: N/A				
Date Started: 5/26/09							Datum Elev: N/A				
Date Completed: 5/26/09							WL Below Datum: N/A				
Contractor: Yellow Jacket Drilling							ATD/Time: 55 FT/14:20				
Drilling Equipment: Hollow-stem auger							Static/Date: N/A				
Depth (Ft)	Geologic Log	Blow Count	Interval	Sample Number	PID/OVA	USCS Symbol	Material Description	Comments			
5							Soil cover (per cover specifications, 3 feet monolithic engineered fill consisting of a 2 ft infiltration control layer compacted to minimum 90% of dry density and 1 ft foundation layer placed over existing cover, which was a minimum of 1 ft thickness above waste).				
10				10'			Waste materials observed included newspapers, plastic bags, paper, glass, wood, plastic, rubber mat, rubber belts, plastic wrap, cardboard, shoe insole, metal, foam rubber, and shredded unidentifiable materials. Appeared to be typical household type waste. Dry to moist, gray to dark colored, and somewhat decomposed, increasing with depth. Identified newspaper store coupon that was good through July 1985 and newspaper movie schedule for "Goonies," which was first released June 7, 1985. Cores of paper, newspapers, and glass in sampler at 10 ft.				
15				15'			Grayish colored odiferous soil in sampler, with only small amount of waste on top of soil.				
20				20'			About 4 inches of waste with soil on top in sampler and stiff core of plastic in drive shoe on first attempt. Core of wood in drive shoe on second attempt.				
25				25'			Metal (aluminum can?), plastic wrap, plastic garbage bags, and cardboard in sampler.				
30											

Project Name: PSOMAS – Vincent Mullins LF/Kolb Rd Project				Log of Boring No: B7		Page 2		of	2
Logged/Checked by: Patricia M. Hartshorne, R.G.				WL Datum: N/A					
Date Started: 5/26/09				Datum Elev: N/A					
Date Completed: 5/26/09				WL Below Datum: N/A					
Contractor: Yellow Jacket Drilling				ATD/Time: 55 FT/14:20					
Drilling Equipment: Hollow-stem auger				Static/Date: N/A					
Depth (Ft)	Geologic Log	Blow Count	Interval	Sample Number	PID/OVA	USCS Symbol	Material Description	Comments	
35				35'			Red brick, pieces of plastic, plastic bags, and metal waste in sampler; waste materials dark colored and moist.		4 bags of 3/8" Bentonite chips added (from ~43-55')
40				40"			Plug of wood, foam rubber type sheet, and gray to black soil in sampler; materials were moist.		
45				45'			Estimated base of waste layer and top of underlying soil.		
50				50'			No recovery on first or second attempts to sample at 45 ft; due to rock?		
55				55'			Low recovery, pulverized white rock in sampler.	TD = 55'	
60									

APPENDIX C

PHOTOGRAPHS

CENTERLINE BORINGS B1, B3, B5, AND B7

Photograph 1. Using hollow stem auger drilling rig to drill boring B1 at the closed Vincent Mullins Landfill.



Photograph 2. Waste materials in drill cuttings between 10 and 15 feet below ground surface (bgs) in boring B1.



Photograph 3. Waste materials in sampler at 15 feet bgs in boring B1.



Photograph 4. Waste materials in sampler at 25 feet bgs in boring B1.



Photograph 5. Clean soil in sampler at 35 feet bgs in boring B1.



Photograph 6. Waste materials in sampler at 15 feet bgs in boring B3.



Photograph 7. Waste materials in drill cuttings between 15 and 25 feet bgs in boring B3.



Photograph 8. Waste materials in sampler at 25 feet bgs in boring B3.



Photograph 9. Rocks and sand in sampler at 35 feet bgs in boring B3.



Photograph 10. Waste materials in sampler at 15 feet bgs in boring B5.



Photograph 11. Waste materials in cuttings between 15 and 25 feet bgs in boring B5.



Photograph 12. Waste materials in sampler at 25 feet bgs in boring B5.



Photograph 13. Soil in cuttings below 35 feet bgs in boring B5.



Photograph 14. Sequential Photographs 14 through 17 show waste in soil cuttings in boring B7 as the boring is drilled deeper (between 7 and 44 feet bgs).



Photograph 15



Photograph 16



Photograph 17

WESTERN BORINGS B2, B4, AND B6

Photograph 18. Soil and a small amount of waste material in sampler at 15 feet bgs in boring B2.



Photograph 19. Soil and waste in sampler at 15 feet bgs in boring B4.



Photograph 20. Grayish colored soil in sampler at 20 feet bgs in boring B4.



Photograph 21. Clean soil in sampler at 25 feet bgs in boring B4.



Photograph 22. Using air knife to clear B6 boring location of potential header pipe to depth of 7 feet bgs prior to drilling.



Photograph 23. Waste in cuttings in boring B6 between 13 and 23 feet bgs.

APPENDIX D

SETTLEMENT CALCULATIONS

VINCENT MULLINS LANDFILL --SETTLEMENT ESTIMATES (e=2.0)							
WASTE DEPTH	STRESS @ CENTER	NEW SOIL THICKNESS (EQUIVALENT LOAD)	INDUCED STRESS @ CENTER	VOID RATIO	Coeff. Of Compression	ESTIMATED SETTLEMENT	PERCENT CHANGE IN THICKNESS
(H in feet)	(Po in psf)	(feet)	(dP in psf)	(e)	(Cc)	(S, in feet)	
4.0	78.0	8	1000	2.00	0.12	0.18	4.56%
7.0	136.5	8	1000	2.00	0.12	0.26	3.68%
10.0	195.0	8	1000	2.00	0.12	0.31	3.15%
20.0	390.0	8	1000	2.00	0.12	0.44	2.21%
21.0	409.5	8	1000	2.00	0.12	0.45	2.15%
26.5	516.8	8	1000	2.00	0.12	0.50	1.87%
38.0	741.0	8	1000	2.00	0.12	0.56	1.48%
40.0	780.0	8	1000	2.00	0.12	0.57	1.43%

WASTE AND SOIL PARAMETERS		
Waste Void Ratio	2.00	
Wet Waste Unit Wt.	39.00	pcf
New Soil Density	125.00	pcf
Compression factor	0.06	

VINCENT MULLINS LANDFILL --SETTLEMENT ESTIMATES (e=3.0)							
WASTE DEPTH	STRESS @ CENTER	NEW SOIL THICKNESS	INDUCED STRESS @ CENTER	VOID RATIO	Coeff. Of Compression	ESTIMATED SETTLEMENT	PERCENT CHANGE IN THICKNESS
(H in feet)	(Po in psf)	(feet)	(dP in psf)	(e)	(Cc)	(S, in feet)	
4.0	58.5	8	1000	3.00	0.18	0.23	5.66%
7.0	102.4	8	1000	3.00	0.18	0.33	4.64%
10.0	146.3	8	1000	3.00	0.18	0.40	4.02%
20.0	292.5	8	1000	3.00	0.18	0.58	2.90%
21.0	307.1	8	1000	3.00	0.18	0.59	2.83%
26.5	387.6	8	1000	3.00	0.18	0.66	2.49%
38.0	555.8	8	1000	3.00	0.18	0.76	2.01%
40.0	585.0	8	1000	3.00	0.18	0.78	1.95%

WASTE AND SOIL PARAMETERS			
Waste Void Ratio	3.00		
Wet Waste Unit Wt.	29.25	pcf	
New Soil Density	125.00	pcf	
Compression factor	0.06		